

23 种顶蒴藓类孢子形态的观察*

杜桂森¹, 汪楣芝², 张玉龙²

(1 首都师范大学生物系, 北京, 100037; 2 中国科学院植物研究所, 北京, 100093)

摘要 报道了中国 23 种顶蒴藓类孢子的形态特征。观察结果显示: 孢子形状有两类, 球形和卵球形。孢子直径可分为 4 组: $10\mu\text{m}$ 以下、 $11 \sim 20\mu\text{m}$ 、 $21 \sim 30\mu\text{m}$ 和 $31\mu\text{m}$ 以上。萌发孔有 3 种类型: 近极薄壁区、单裂缝和无萌发孔。外壁纹饰有 4 种: 棒状、瘤状、疣状和鼓槌状。孢子颜色有 6 种: 黄褐色、黑褐色、淡黄褐色、金黄色、草绿色和紫红色。

藓类孢子体积不同物种间有差异, 但球形和卵球形是基本类型。苔藓孢子的萌发孔有 3 种类型: 三裂缝为原始类型, 单裂缝是进化性状, 近极薄壁区是最常见的。苔藓孢子的外壁纹饰不同, 一般认为孢子外壁光滑是进化性状, 外壁上各种突起排列密集的则较为原始。孢子的颜色在遗传上具有相对稳定性, 可能与生活环境、孢壁厚度、孢子体积、叶绿体数量和贮存物质有关。孢子颜色在分类和系统发育上的意义还有待于观察和探讨。

关键词 顶蒴藓类; 孢子形态; 系统发育

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Observations of Spore Morphology of Some Acrocarpous Mosses in China

DU Gui-Sen¹, WANG Mei-Zhi², ZHANG Yu-Long²

(1 Department of Biology, Capital Normal University, Beijing 100037, China;

2 Institute of Botany, Chinese Academy of Sciences, Beijing 100093, China)

Abstract: Spore characters of 23 acrocarpous moss taxa in China are reported. Observation results show that (1) there are two types of spore shape, namely spherical and ovoid; (2) the spore diameter can be divided into four groups, namely under $10\mu\text{m}$, $11 \sim 20\mu\text{m}$, $21 \sim 30\mu\text{m}$ and over $31\mu\text{m}$. There are three types of aperture, namely katelept, monolete and atreme. There are four kinds of exine ornamentation, namely baculate, tuberculate, verrucate and pilate. There are six of spore color, namely yellow brown, dark brown, yellowish green, golden yellow, grass green and purple.

The size of moss spores are different from species, but the basic types are spherical and ovoid. Bryophyte spores have three types of aperture, the trilete is original one, the monolete is the evolutionary character and the katelept is mostly common one. The ornamentation of exosporium varies from species. The smooth exine is considered to be an evolutionary character. It is considered to be an original character that various processes densely arranged on the exine. The spore color is relatively stable on genetics, it probably

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is related with living environment , sporoderm thickness , spore volume , chloroplast quantity and storage products. The significance of spore color in taxonomy and phylogeny remains to be further observation and investigation.

Key words : Acrocarpous moss ; Spore morphology ; Phylogeny

Spores have important significance in the taxonomy and phylogeny of bryophytes (Clarke , 1979 , Mogensen , 1981). Spore morphology may be quite variable between taxa. However , within a taxon , spore characteristics are genetically and relatively stable. Moss spores range in size from about 5 ~ 200 μm with the majority between 10 ~ 50 μm . The application of scanning electron microscopy to the study of bryophyte spores has permitted the careful observation of structural details which are often not visible with conventional light microscope. In this paper we present the results of a study on the spore morphology from 23 species of Acrocarpous mosses in China.

1 Material and methods

Specimens used for this study were collected in Hebei , Sichuan , Yunnan and Xizang provinces. For each species 20 spores were measured by using light microscop (LM). The spores were examined by LM after actolysis. For scanning electron microscopy (SEM) , spores were mounted on double sided adhesive tape attached to metal stubs , coated with gold in an Ion Sputter Coater and examined by using HITACHI S - 800 SEM .

2 Results

The spore characteristics of the 23 species studied are summarized in Table 1. All species produce monad spores derived from the separation of four daughter cells in a tetrad after meiosis of the spore mother cell. The shape of the spores varies between the two types of spherical and ovoid. The spore compression within developing tetrads in a capsule may result in the distal surface being rounded while the proximal surface comprises three flattened triangle.

The color of the mature spores varied from yellow brown to dark brown or purple and from golden yellow to yellow green or grass green. The color of the spore mass depends on age , exinous thickness , size and number of chloroplast and the presence of storage products in the spore (Mueller , 1974).

Four classes of spore diameter are recognized. 15 species studied had spores ranging from 11 μm to 20 μm in diameter , 6 species had spores ranging from 21 μm to 30 μm , while *Physcomitrium sphaericum* has spores diameter over 31 μm and *Bryum uliginosum* spores diameter under 10 μm .

Three types of germinal aperture were recognized , the katalept with three different shapes - triangular (8 species) , the polygonal (10 species) or rhomboidal (2 species) , the monolete (1 species) and the non - aperture one (2 species).

Four types of exinous ornamentation were recognized. (1) Baculate with the ektexine has tiny surface rods , which are not thickened at either end , but vary widely in size. They may occur in isolation or in clusters. There are 18 species represented in this group. (2) Tuberculate with the ektexine

Table 1 Morphological characteristics of spores of 23 acrocarpous moss taxa from China						
Species	Spore diameter range&(mean) μm	Spore shape	Spore color	Aperture (SEM)	Exine ornamentation (SEM)	Voucher
<i>Bryumargenteum</i>	10.9(13.2)14.1	Ovoid	Yellow brown	Quadrangular katalept	Baculate	Hebei ,Wuling Shan ,Du Gui-sen W9472
<i>B . lonchocaulon</i>	25.0(27.9)31.3	Spherical	Yellow brown	Polygonal katalept	Sparsely baculate or tuberculate	Hebei ,Wuling Shan ,Du Gui-sen W9356
<i>B . uliginosum</i>	7.8(9.8)10.9	Ovoid	Yellow brown	Triangular katalept	Small baculate or tuberculate	Hebei ,Wuling Shan ,Du Gui-sen W9318
<i>B . arcticum</i>	25.0(28.2)31.3	Spherical	Yellow brown	Quadrangular katalept	Sparsely baculate	Hebei ,Wuling Shan ,Du Gui-ser W9525
<i>B . pallescens</i>	20.3(21.8)25.0	Ovoid	Yellow brown	Triangular katalept	Baculate , small apical spinate processes	Hebei ,wuling Shan ,Du Gui-ser W9237
<i>B . alpinum</i>	10.9(12.9)15.6	Spherical	Yellow brown	Polygonal katalept	Long baculate , smooth apical processes	Hebei ,Wuling Shan ,Du Gui-sen W9546
<i>B . caespiticium</i>	22.2(22.8)26.4	Ovoid	Golden yellow	Triangular katalept	Irregular small baculate , nearly smooth apical processes	Xizang ,Yadong ,Xizang Dui # 7845
<i>B . pallens</i>	10.5(11.3)13.6	Ovoid	Yellowish green	Rhombic katalept	Regularly baculate ,nearly smooth apical processes	Xizang , Milin , Xizang Dui # 7494
<i>B . pseudotriquetrum</i>	19.4(21.6)25.0	Ovoid	Yellowish green	Polygonal katalept	Small , irregularly sparse baculate , small apical processes	Xizang , Chayu , Wang Mei-zhi # 12797-b
<i>B . paradoxum</i>	15.5(17.9)21.9	Spherical	Yellow brown	Elliptic-triangular katalept	Short , arranged dense baculate , granular apical processes	Yunnan , Gong Shan , Wang Mei-zhi # 9373-a
<i>B . thomsonii</i>	16.7(18.3)20.8	Ovoid	Yellow brown	Polygonal katalept	Dense baculate , nearly smooth apical processes	Xizang , Linzhi , Lang Kai-yong # 675
<i>B . coronatum</i>	8.3(10.2)11.1	Spherical	Yellowish green	Polygonal katalept	Regularly arranged sparse short baculate	Yunnan , Menghai , Lou Jian-xin # 86370
<i>Bryum sauteri</i>	15.3(18.0)20.0	Ovoid	Yellow brown	Triangular katalept	Pilate ,nearly smooth terminal processes	Sichuan ,Ma Er Kang , He Si # 31279
<i>Oncophorus virens</i>	14.1(16.1)20.3	Ovoid	Yellow brown	Triangular katalept	Baculate , microechinate above	Hebei ,Wuling Shan ,Du Gui-ser W95011
<i>Physcomitrium sphaericum</i>	40.6(45.8)51.6	Ovoid	Yellow brown	Monolete	Sparsely arrange baculate	Beijing ,Xiang Shan ,Du Gui-ser Y9401
<i>Funaria hygrometrica</i>	14.1(16.1)20.3	Spherical	Grass green	Triangular katalept	Densely arranged baculate microechinate above	Beijing ,Xiang Shan ,Du Gui-ser Y9402
<i>Bartramia pomiformis</i>	23.4(24.9)26.6	Spherical	Purple	Small triangular katalept	Pilate ,with nearly smooth apical processes	Hebei ,Wuling Shan ,Du Gui-ser W95026
<i>Anoetangium thomsonii</i>	8.3(11.0)12.5	Ovoid	Yellow brown	Polygonal katalept	Irregularly arranged verrucae ,small granular terminal processes	Hebei ,Wuling Shan ,Du Gui-ser W9459
<i>Weisia viridula</i>	16.7(17.9)20.8	Ovoid	Dark brown	Nonaperture	Pilate ,with nearly smooth terminal processes	Hebei ,Wuling Shan ,Du Gui-ser W9248

续表 1

Species	Spore diameter range&(mean) μm	Spore shape	Spore color	Aperture (SEM)	Exine ornamentation (SEM)	Voucher
<i>Bryoerythrophyllum recurvirostrum</i>	12.5(13.3)-13.9	Ovoic	Yellowish green	Rhombic katalept	Irregularly baculate ,small spinate processes terminally	Hebei ,Wuling Shan ,Du Gui-ser W9517
<i>B. yunnanense</i>	13.9(14.9)-16.7	Ovoid	Yellowish green	Polygonal katalept	Sparsely and irregularly baculate	Hebei ,Wuling Shan ,Du Gui-ser W9326
<i>Tortula muralis</i>	9.7(11.4)-13.9	Ovoid	Golden yellow	Polygonal katalept	Densely baculate , nearly smooth terminal processes	Hebei ,Wuling Shan ,Du Gui-ser W9511
<i>T. mucronifolia</i>	15.3(17.1)-19.4	Ovoid	Yellowish green	Nonaperturate	Irregularly tuberculate , nearly smooth terminal processes	Hebei ,Wuling Shan ,Du Gui-ser W9534

Voucher specimens have been deposited in the Herbarium of Institute of Botany ,Chinese Academy of Sciences ,and in the Herbarium of Capital Normal University .

has peg – like projections . This group is represented by *Tortula mucronifolia* (Plate II : 6) . (3) Verrucate with the ectexine is covered by small wart – like knobs or projections , represented by *Anoetangium thomsonii* . (4) Pilate with the ectexine appears as slender (hair like) club – like projections with spherical terminal knobs . This group is represented by three species .

3 Discussion

In China , the study of moss spore morphology began in the 1980s (Gao and Cao , 1984 ; Cao and Vitt , 1988 ; Zhang and Wu , 1990) , although most of the species studied were in *Sphagnum* , *Physcomitrella* (Li and Wu , 1988) and *Pterygoneurum* (Wu and Wang , 1994) . The 23 species we have studied are representatives of the orders of *Pottiales* (7 species) , *Bryales* (13 species) and *Funariales* (3 species) . None of the spores studied had a smooth exine . It can be seen from Plate I ~3 that all the species studied have spores with the exinous ornamentation , of which arranged are densely or sparsely in the processes . Exinous ornamentation appears to be more useful in separating the higher order groups rather than the differentiating closely related taxa , and is more useful in taxonomy rather than in features of these spores , such as colour of the spore mass that may differ between congeneric taxa .

The spores of the majority of taxa studied were yellow – brown or yellow – green spores in colour . While the spore colour is possibly related to the characteristics of habitat . It is apparently not a useful taxonomic feature .

Aperture characteristics are difficult to confirm with scanning electron microscopy , largely due to the lack of control over orientation of the spores on the mounting stubs . While the monolete character is regarded as being evolutionarily advanced , so far the majority of the spores examined were katalept forms .

A smooth exine is also considered as an advanced feature . The spore exine of all the taxa exam-

ined is variously ornamented. According to the above principle, spores having dense processes are primitive, while those having sparsely arranged processes are comparatively advanced. Most of the *Bryum* species, *Pottiales* and *Funariales* taxa examined would, by their spore ornamentation, be considered more advanced. On spore morphology, *Tortula mucronifolia* and *Anoetangium thomsonii*, having densely arranged exine processes, would be considered less advanced.

For the taxa studied we consider spore morphology, particularly the detail revealed with use of the scanning electron microscope, to be a particularly useful taxonomic tool, but more useful in differentiating at higher taxonomic levels than at the specific level.

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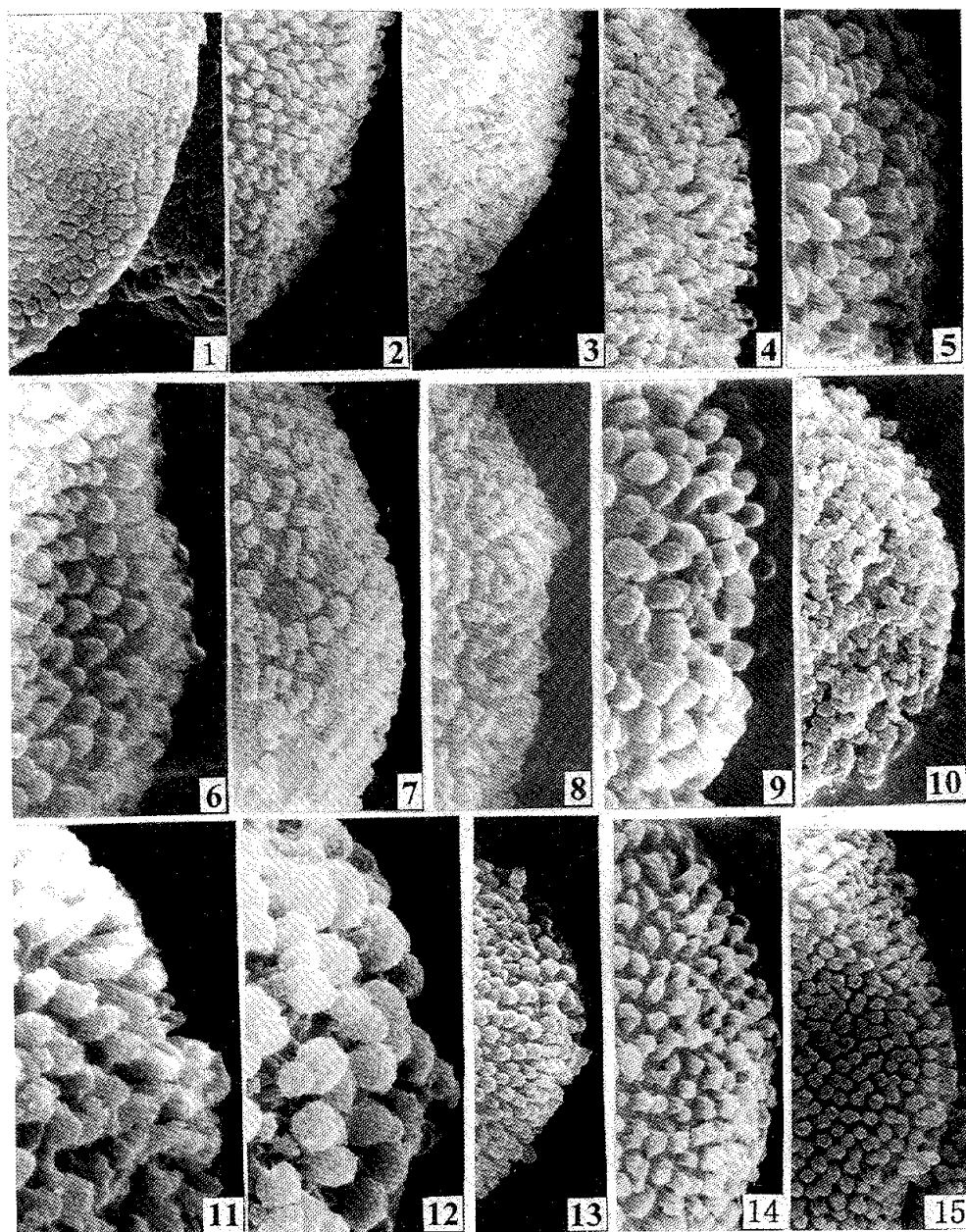
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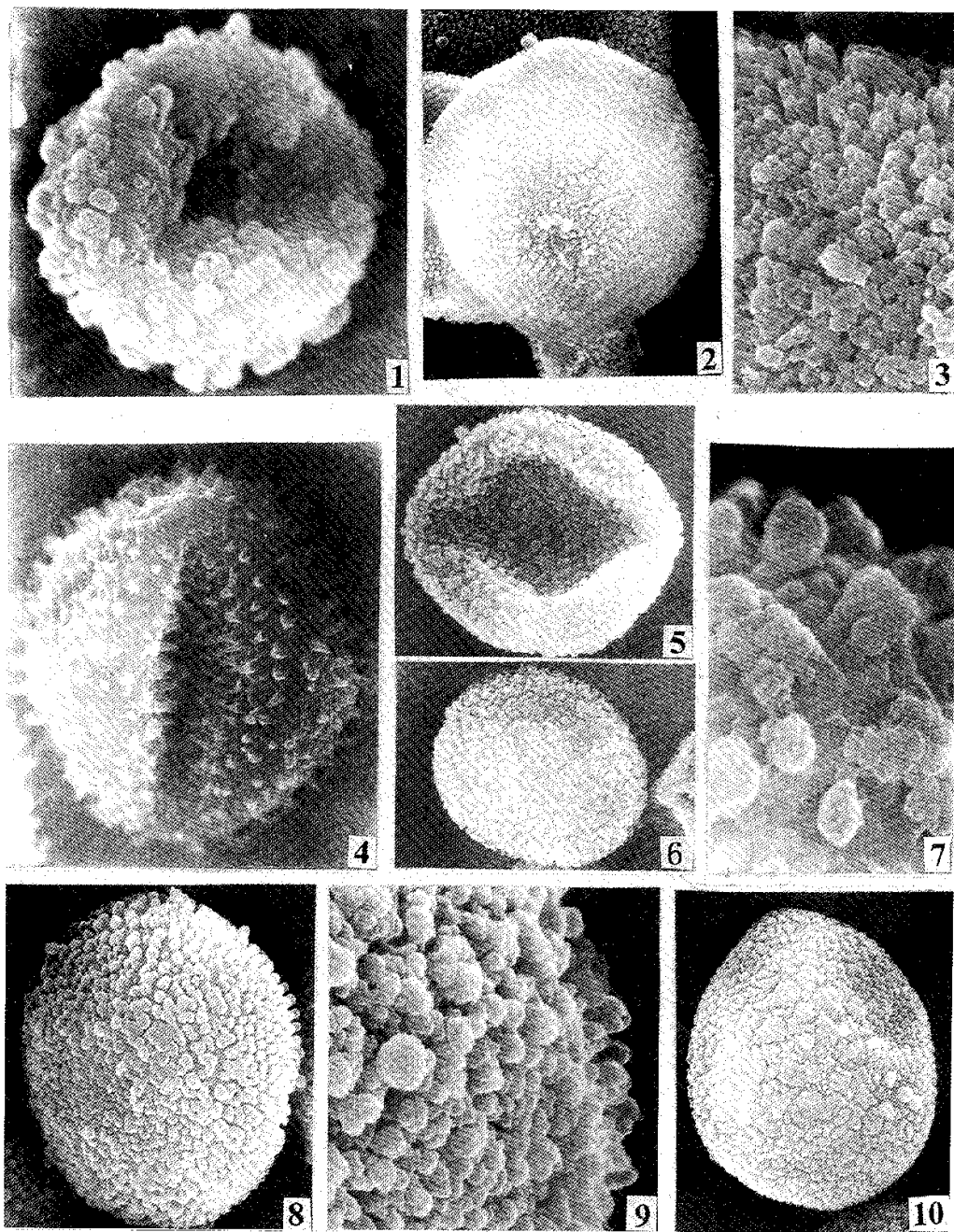
Explanation of Plates

Plate I. Exine ornamentation of spores of Acrocarpous moss taxa from China. 1. *Bryum argenteum* Hedw. , $\times 10000$. 2. *B. lonchocaulon* C. Muell. , $\times 10000$. 3. *B. arcticum* (R. Br.) B. S. G. , $\times 10000$. 4. *B. Caespitium* Hedw. , $\times 10000$. 5. *B. sauteri* B. S. G. , $\times 10000$. 6. *B. pallescens* Schleich. ex Schwaegr. , $\times 20000$. 7. *Tortula mucronifolia* Brid. , $\times 10000$. 8. *B. pseudotriquetrum* (Hedw.) Schwaegr. , $\times 20000$. 9. *B. coronatum* Schwaegr. , $\times 20000$. 10. *Tortula muralis* Hedw. , $\times 10000$. 11. *Bryum pallens* Sw. , $\times 20000$. 12. *Weissia controversa* Hedw. , $\times 10000$. 13. *Bryum uliginosum* (Brid.) B. S. G. , $\times 10000$. 14. *Bryoerythrophyllum recurvirostre* (Hedw.) Chen. , $\times 10000$. 15. *Bryum alpinum* With. , $\times 10000$.

Plate II Characteristics of spores of Acrocarpous moss taxa from China. 1. *Bartramia pomiformis* Hedw. , katalept , $\times 3000$. 2. *Bryum lonchocaulon* C. Muell. , spherical spore $\times 3500$. 3. *B. thomsonii* Mitt. , exine ornamentation , $\times 10000$. 4. *Physcomitrium sphaericum* (Ludw.) Fuernr. , aperture and exine ornamentation , $\times 2000$. 5. *Bryoerythrophyllum recurvirostrum* (Hedw.) Chen. , katalept , $\times 3500$. 6. *Bryum pallens* Sw. , ovoid spore , $\times 3500$. 7. *Bartramia pomiformis* Hedw. , exine ornamentation , $\times 7500$. 8. *Bryum uliginosum* (Brid.) B. S. G. , ovoid spore $\times 3500$. 9. *B. paradoxum* Schwaegr. , exine ornamentation , $\times 10000$. 10. *B. pallescens* Schleich. ex Schwaegr. , ovoid spore , $\times 3500$.



See explanation at the end of text



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